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ENERGY RESOURCES

Energy-saving strategies and measures to improve the efficient
utilization of electric power systems

Report of the Secretary-General

SUMMARY

Produced in response to Economic and Social Council resolution 1989/6 of 22 May 1989, the present report summarizes the critical issues involved in the efficient generation, transmission, distribution and utilization of electric power, and emphasizes the cost-effectiveness of various power plant operation, maintenance and rehabilitation programmes. It stresses systematic plant operation and maintenance in order to reduce both technical and non-technical power losses. In view of the scarce investment capital available for the construction of new and more efficient power generation plants, the rehabilitation of existing units should be accorded the highest priority. The report proposes methods for most efficiently transferring power-sector efficiency technologies to developing countries and concludes with recommendations that the Committee might wish to consider.

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INTRODUCTION

1. This report has been prepared in response to Economic and Social Council resolution 1989/6 of 22 May 1989 in which the Council requested the Secretary-General to submit a report to the Committee on Natural Resources at its twelfth session on energy-saving strategies and measures to improve the efficient utilization of the electricity system.
2. It is now generally recognized that energy conservation and improved efficiency of existing facilities are the most cost-effective ways to increase the supply of energy needed by both urban and rural sectors in developing countries. These approaches also allow developing countries to reduce energy costs, stretch their energy supply base without heavy sectoral investment, save foreign exchange, and contribute to the global environmental protection effort.
3. The underlying concern in this area is that in many developing countries the energy sector physical infrastructure is deteriorating rapidly. In some countries, this is the result of aging infrastructure which is operating beyond its intended economic life. In several countries, however, the deterioration is more a result of systematic lack of plant operation and maintenance, sometimes traceable to the lack of foreign exchange needed for essential spare parts. Proper maintenance and operation of a power system reduces both technical and non-technical losses. In view of the scarce investment capital available for installation of new and more efficient power generation plants, rehabilitation of existing units should be accorded the highest priority.
4. This technical paper summarizes the critical issues involved in the efficient utilization of electric power systems, issues that have been the focus of serious debate at many international meetings. Sections I-IV deal with power system planning, operational and maintenance procedures, plant rehabilitation and modernization, and reduction of transmission and distribution system losses. Section V discusses the technical and economic advantages of regional power-system interconnections which offer developing countries lower generation costs, lower reserve capacities and increased supply security.
5. Section VI discusses the financial and institutional aspects of energy-saving strategies in the power sector and their transfer-of-technology and training implications. The paper concludes with recommendations that the Committee on Natural Resources may wish to consider which would assist and guide developing countries, donor Governments and agencies, and implementing agencies in their attempts to increase power-sector efficiency and reduce energy costs.

I. SYSTEM PLANNING, INCLUDING DEMAND-SIDE MANAGEMENT AND LIFE-CYCLE COST INVESTMENT PLANNING

6. A properly functioning energy supply system is of critical importance to the economic and social development of all countries, both developed and developing, and has been so recognized by Governments, international institutions and agencies

world wide. Energy sources with higher end-use efficiencies have gradually replaced traditional fuels like wood. One result has been that electricity now accounts for an increasing share of total final energy consumption.

7. System planning, in its broadest sense, is the key to attaining a well functioning and efficient electricity supply. It is a critical requisite for all power companies and especially important for developing countries faced with increasing electricity and energy demands. System planning has four time phases: perspective planning, operational planning, medium-range planning, and long-range planning.

8. The aim of perspective planning is to indicate the long term development of the energy and power sectors. It may, *inter alia*, indicate the fields in which research and development programmes should be concentrated. Operational planning deals with short-term activities where maintenance is a key component.

9. Medium-range planning covers development over the next two to five years. It indicates if minor changes in the construction programme are needed - e.g., delay or speeding up of some projects or inclusion of some new projects with short lead times, such as gas turbines.

10. Long-range planning covers the next 5-15 years and is needed for basic planning of the generation and transmission systems. The lead time - the time that elapses between the date a decision is made to construct a new large power plant and the date on which the plant can be put into operation - is today very long in most countries, usually at least five years for large conventional thermal power plants and up to 10 years or more for large hydro and nuclear power plants. Long-range planning comprises three types of activities:

(a) General system studies on electricity demand and its variations, required reliability of supply, costs of new power plants, costs of improving supply availability of existing plants, demand-side management, long-term power purchase/sale/sharing agreements with other companies, future availability of fuels and their prices, capital costs of an operations and maintenance organization, environmental influences, and political/financial factors influencing the construction programme;

(b) Technical and economic feasibility studies for possible projects that could be included in the development programme, including rehabilitation of existing plants;

(c) Establishing the optimal power development programme in order to meet anticipated electricity demand with required reliability and at lowest cost, with due regard to the environment and other constraints.

11. It is obvious that due consideration must be given to the specific conditions prevailing in each country. The planning process will consequently be different in countries where one national power company has a practical monopoly on the power supply sector as compared to countries where several important power companies exist. Even in the latter case, each power company must perform its own system

planning, but co-operation would be needed for overall national objectives to be achieved.

12. Long-range forecasts can be of several types:

- (a) National forecasts based on general economic indicators;
- (b) Forecasts based on discussions with different groups of consumers;
- (c) Regional/partial forecasts based on discussions with regional utilities and large consumers.

The most important factors influencing electricity demand are the electricity price level and the tariff structure. Realistic electricity tariffs are an important component of demand-side management now used by many power companies to influence future electricity demand. Its aim is to promote energy conservation so that the value of using an additional kilowatt-hour (kWh) at least equals the costs of supplying the same kWh with new capacity, taking environmental costs into consideration. Demand-side management is especially important when electricity tariffs for some reason do not reflect the marginal cost of electricity supply.

13. The capacity needed to meet estimated total demand depends on the availability of generating equipment and the required security of supply. With low security of supply, consumers could be faced with many and long supply outages. Since 100 per cent security of supply is very expensive and often impossible to attain, an optimal level of supply security has to be aimed at. This can be achieved by estimating the economic value of electricity not supplied to consumers - the outage costs - and comparing that value with the marginal costs for increasing the supply through higher reliability of supply.

14. The value assigned to outage costs depends on several factors, including the stage of development of the country. In Sweden, studies have shown that outage costs (1989 prices) are about \$US 5.0 per kWh for interruptions under one hour and about \$US 0.5 per kWh for long interruptions (weeks, months) caused by energy rationing. Assuming a certain level of outage costs and knowing the marginal costs for increased system capacity, an optimal reliability of system supply can be established. For the example mentioned above, this corresponds to about 0.1 per cent risk of shortage of capacity during the peak period (equal to eight hours of interruption per year) and 3.0 per cent risk of shortage of energy generation (equal to a shortage once every 33 years).

15. In many developing countries, supply reliability is low due to inadequate power generation/transmission capability to meet system demand. The reasons may be shortage of investment capital for new plants, low availability of existing plants or low electricity prices, and the resulting costs are high, counteracting the benefits of efficient system planning.

16. In order to establish an optimal power development programme, alternative proposals for new plants have to be studied from technical and economic viewpoints. To compare different types of projects, one must take into account all

costs during the real lifetime of the projects - i.e., the life-cycle costs (LCC). It is especially important to include realistic figures for all operational and maintenance costs as well as costs of losses. The remaining value of the plant at the end of its operational lifetime also has to be considered. The LCC principle is useful for detailed plant design. Differences in operation and maintenance models can in this way be directly translated into costs and revenue. This emphasizes the close connection between plant design and the operation/maintenance concept and demonstrates the necessity of planning these activities during plant design.

17. Experience has shown that international fuel costs vary considerably over time and that the future trend of fuel prices is extremely difficult to forecast. Capital costs are the most important cost items for most power plants and depend on the lifetime of the plant (amortization) and the rate of interest. For comparing different projects, costs should be expressed in real or constant terms. In developing countries with regulated exchange rates, costs have to be divided into local currency costs and foreign exchange costs (generally expressed in dollars).

18. The availability of supply from power plants usually decreases with time, slower for hydro power plants and quicker for thermal power plants. This development can be counteracted through proper maintenance. Inevitably, however, maintenance costs will grow with time. Through rehabilitation, plants can be upgraded and supply availability increased. There is today a definite trend towards a longer lifetime for most power plants. Operating lifetimes of 60-70 years are thus relatively normal for hydro plants. While 30 years was earlier considered to be a normal lifetime for conventional thermal power plants, during the past decade many thermal plants have lengthened their lifetimes through more extensive maintenance and rehabilitation. In the future, several thermal plants may operate reliably for over 60 years.

19. The above-noted trend proves that improved maintenance and rehabilitation of existing older plants is a realistic alternative to building new plants. In many developing countries, the availability, especially for thermal power plants, is unacceptably low and figures of 50 per cent and lower have been cited by the World Bank. Improving the availability - the percentage of installed capacity actually ready to go into operation - is often a less expensive alternative than building new plants. The possibilities for such improvements should therefore be considered in system planning.

20. Each utility has to investigate its own possible new power contributions. There are usually possibilities to co-operate with neighbouring companies. It may thus be more economical to buy power under a long-term contract than to build new power plants. The benefits of such co-operation are described in section V below. Large electricity customers, especially industries, may be able to build power plants that use waste heat from industrial processes, thereby lowering fuel costs significantly; others can often build combined power and heat plants that are highly efficient. These possibilities should be encouraged through special agreements between utilities and consumers. A utility may also be able to buy surplus power from another co-operating utility and thus improve the total economy of fuel use; such power may be used in electrical boilers and to replace fuels otherwise needed for steam or hot water production.

21. Compared to fossil fueled plants, hydro power plants have relatively smaller environmental impacts. Nuclear power generation is still a very complex and highly capital-intensive process which must be based on large units to be economical. It also requires very careful design, construction and operation if serious accidents are to be avoided. Most developing countries continue to rely on thermal power generation despite problems of emissions of sulphur oxides and nitrous gases, dust, heated water used in the cooling process and ash disposal. Modern technical equipment can reduce these problems but is expensive to install and operate. Grants and soft loans from industrialized countries and international financing institutions can assist developing countries reduce the environmental damage described above.

22. Evaluating all possible alternatives for new power contributions and the required security of supply, it is possible to establish an optimal power development programme to meet future electricity demand. The different types of power contributions should be combined in such a way that the resulting supply system will imply minimum system costs. The period considered may vary between 5 and 15 years depending on the types of power contribution. For large power systems, the calculations needed are voluminous and complex, and computerization is essential.

23. The long-term power development programme must continuously be checked against actual developments. System demand may deviate to different degrees from the long-term forecast, and other factors may change the economics of new power contributions. For these reasons it is necessary to check the power development programme at relatively short intervals, perhaps as often as every year, but usually every two to three years, and adjust the original power development programme accordingly.

24. System planning does not end with the establishment of power development programmes. It also includes planning the operation of the system. This is normally a two-year future planning process that takes into account power demand distribution over the period, maintenance schedules, power capability restrictions, the availability of plants (especially thermal), fuel costs, limited water storage volumes, water inflow forecasts, power exchange possibilities, legal and environmental restrictions, and other considerations.

25. The calculations involved in operational planning result in forecasts of short-run marginal costs for the system. Those marginal cost values provide guidelines for the disposition of hydro plant reservoirs (in the form of "water values") and for thermal power generation and possible short-term power exchanges with co-operating companies.

26. Power plant system operation is today a heavily computerized activity which, through complex programmes, takes into account all the factors necessary to achieve an optimal division of power contributions from all available sources and in this way determines the short-run marginal costs of the system.

II. SYSTEMATIC MAINTENANCE PROCEDURES AND IMPROVED OPERATIONAL ROUTINES TO INCREASE POWER SYSTEM RELIABILITY AND AVAILABILITY

27. Proper maintenance is a necessity for all power installations, in order to ensure high availability and efficient operation and minimize adverse impact on the environment. Maintenance costs should therefore not be regarded as an unnecessary cost item but rather as an investment to achieve good operational results. Investments in new plants are often considered more glamorous and have been easier to finance than investments for rehabilitation and maintenance. It is important to change these attitudes. The primary aim of maintenance activities is to protect basic equipment so as to guarantee high availability and efficiency and to extend the economic life of power installations.

28. The productivity of a power plant can be defined by the following two simple formulae:

(a) $\text{Productivity} = \text{Production} / \text{Resources}$

(b) $\text{Production} = \text{Capacity} \times \text{Time} \times \text{Availability}$
 $= \text{Available Capacity} \times \text{Time}$

29. High productivity is thus defined as the smallest level of resources needed to generate the highest level of output. The required high output level can be achieved by sustaining or improving nominal plant capacity and by assuring high available capacity during the time the plant is in operation. Resources include human resources, services, spare parts, consumables, and the financing of needed additional investments.

30. The importance of high supply availability as a key to productivity has been recognized for several years by certain international bodies. The World Energy Council and the International Union of Producers and Distributors of Electrical Energy have agreed on a joint definition of the availability factor. It should thus be possible to publish statistics on the "available capacity" of different systems, a measure more important for system operation than either installed or nominal capacity.

31. In industrial countries, overall availability factors are usually 90 per cent or higher for large hydro plants and around 85 per cent for large thermal plants. Large differences do occur, however, partly due to the time needed for annual overhaul and partly due to the age of the plant. The average availability factor for nuclear plants in Sweden has been 85-90 per cent in recent years (unavailability includes about 10 per cent for the annual overhaul).

32. In developing countries, the availability factor is often much lower. According to the World Bank, many developing countries report availability factors at or below 50 per cent. This unavailability is to a great extent caused by forced outages, and indicates that efforts to improve the plant maintenance should have preference over new plant investments.

33. The availability performance of a plant is, in principle, a function of three factors: reliability, maintainability, and maintenance support. The reliability factor is determined by the probability that a component or a system will perform its intended function over a required period under given conditions. Maintainability is the inherent capability of a component or a system to be maintained and is usually determined by the mean time for repair or restoration. Maintenance support is a measure of the ability of the maintenance organization to support maintenance when required and is usually expressed as mean waiting time.
34. This technique of analysing availability is called RAM-engineering (reliability, availability, maintenance). It is based on probability theory and requires that data assembled from the maintenance system be expressed as the failure rate, mean time to repair and mean waiting time. The availability factor reflects the technical capability of a plant to fulfil its function and should not be confused with the "plant load factor" which indicates the production actually achieved. For a peak load power plant, the availability factor might be very high, although the load factor might be low.
35. A maintenance philosophy, well conceived and adapted to the conditions of each plant, is a prerequisite for high productivity. It has to be based on careful analysis of factors including plant planning, design and construction, maintenance principles and methods, management maintenance systems, maintenance staff, and logistical support.
36. To achieve high productivity in a power plant, provisions for plant maintenance have to be incorporated during the planning and design phases of new or rehabilitated plants. Whether the plant will be operated as a base load or peak load plant will influence the maintenance function and may also influence the design of certain components. The same may be the case for the requirements from the transmission system - e.g., as regards stability conditions.
37. The operating mode of the plant will often change dramatically over its life cycle. Thermal power plants may initially operate as base load plants and slowly change to reserve plants by the end of their lifetimes. This is considered in life-cycle cost calculations. To facilitate future maintenance, complete documentation on the technical design and function of all components in the plant should be supplied in the desired language by the manufacturers and constructors. This has to be stressed in the tender documents.
38. Maintenance needs comprise corrective maintenance, preventive maintenance, including overhauls, and rehabilitation. Corrective maintenance meets unplanned breakdowns of plant components. It is obvious that plant availability will decline in proportion to the number of breakdowns with consequent higher maintenance costs. A major objective is thus to shift the majority of maintenance activities from unplanned to planned stoppages through systematic preventive maintenance programmes.
39. Preventive maintenance is based on a systematic approach and performed on a regular basis. It includes such direct activities as cleaning, lubrication, programmed replacements and repairs, together with indirect actions such as regular

inspections and methods for monitoring of equipment condition. The implementation of a preventive maintenance programme requires knowledge and experience in plant and equipment design, component failure development patterns, methods for data measurement and evaluation, resources and capability to plan and perform large volume of preventive maintenance activities, and the ability to systematically co-ordinate maintenance activities with plant operation.

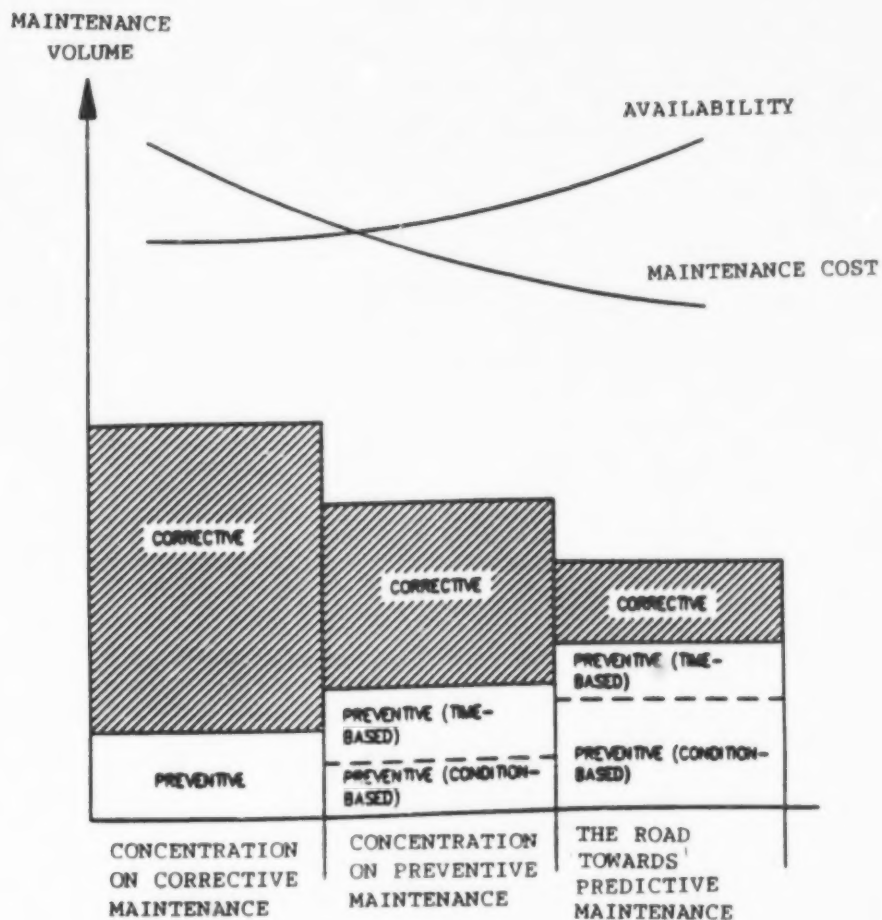
40. Overhauls are preventive maintenance if they comprise large volumes of work, normally executed during a limited period when the plant is taken out of operation. The frequency and scope of overhauls depend on the plant operating mode. Results from systematic condition monitoring and staff experience determine the optimal overhaul programme. The intervals between overhauls for base load thermal power plants vary considerably, depending on the fuel used and the country, but from one to three years may be typical. The largest work volume is generally the boiler. The normal duration for an annual thermal plant overhaul is about four weeks, but it will be about six weeks if the turbine has to be opened. Hydro power plants are in principle less complex than thermal plants, and the interval between overhauls is longer, at least two to five years or longer.

41. Rehabilitation is a major event, usually carried out only once or twice during the plant lifetime. It is not considered normal maintenance and is covered in detail in section III below. Rehabilitation work on a smaller scale - in particular, minor upgrading and modernization of systems and equipment - is included in the normal preventive maintenance programme.

42. Maintenance activities have to be extensively supported by an administrative system which ensures that the logistical functions facilitate these activities. Human resources, spare parts, consumables and other resources must be made available at the proper time and of adequate quality. This is the responsibility of the maintenance management system. Since the aim of preventive maintenance is to stop failures from occurring or to find failures before they cause a serious equipment or plant breakdown, an ideal preventive maintenance programme should include almost every piece of equipment in the power plant.

43. New methods for monitoring equipment condition during operation are becoming more and more common and help to optimize preventive maintenance activities. Extensive efforts are under way, not only to develop new methods for measurements, but also for processing large and complex volumes of data, especially through so-called expert systems. In this way, the need for high-level advanced competence within the plant itself will be reduced. Ultimately, preventive maintenance activities may be characterized as predictive maintenance, as shown in the figure below.

Figure



44. The methods used for preventive maintenance work depend upon the type of power plant, but the main principle is to monitor conditions of the different components of the plant and maintain them before they break down. The traditional form of condition monitoring is based on regular inspections by experienced staff. There is, however, a strong trend today towards more sophisticated methods (and instruments) for condition monitoring, which are often combined with methods to improve plant efficiency and safety.

45. Examples of on-line methods are: key temperature monitoring, vibration monitoring, process water chemistry monitoring, process diagnosis and analysis, and monitoring of operational economics. Modern off-line methods, which complement the on-line methods, include inspections that utilize turbine endoscopes, eddy currents,

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ultrasonic metres, liquid penetrants, magnetic particles, leakage detectors etc. While all the above-named inspections can be performed manually, automatic inspection systems are often used - as, for instance, eddy-current inspections for heat exchanges.

46. The planning, preparation, executing and follow-up of preventive and corrective maintenance activities are challenging tasks for maintenance managers and engineers. The management maintenance system should encompass all maintenance needs and all types of internal and external resources involved in the maintenance function. It must be possible to cope not only with large volumes of planned work but also with the dynamic needs emerging from unexpected equipment breakdowns, and thus flexibility is a must. Of particular interest is the logistical support function, including supply of spare parts, consumables, transportation and lifting equipment, tools, workshops, laboratories, compressed air, water etc. Feedback and analysis of technical factors and resource consumption in economic terms are other important parts of a management maintenance system.

47. A well-designed management maintenance system should include the following modules: equipment records (management data, administrative data etc.); document records (drawings, manuals, instructions etc.); preventive maintenance module (where? when? how often?); and inventory control and purchase administration modules (spare parts, consumables, services etc.).

48. Once a system with these modules has been put into effect and the maintenance organization has become familiar with its use, several other modules can be added gradually, such as personnel, training, chemical data, project cost analysis and follow-up, contractor files etc. While computerization is the rule for a management maintenance system in most industrialized and several developing countries, it is no easy task, since it requires a considerable effort to collect data on equipment, spare parts, drawings, preventive maintenance etc. For new plants, the data collection process can be much easier if it is made as part of the planning and design work.

49. Given the key role of maintenance, more recognition of the work performed by operation and maintenance personnel is justified. In many countries, the low status and payment conditions accorded these employees have led to problems in retaining competent staff. Improved pay structures and the introduction of incentives have had positive results, with increased supply availability and reduced costs for the power company.

50. An appropriate delegation of authority to different levels in the organization will also encourage greater staff motivation and enthusiasm. The employment of qualified personnel has to be complemented with a suitable staff development programme, supported by top management. Staff development has to be recognized as a long-term activity and resources continuously allocated for this purpose. While the costs for retaining and continuously training maintenance personnel are high, they should be compared with the even higher cost of poor maintenance, leading to low plant availability and inefficiency.

51. A successful maintenance work programme requires well planned logistical support in the form of spare parts and workshops as well as suitable external

support. The lack of spare parts is very often the reason for low productivity in power generation. While the need of spare parts is a function of plant design and the reliability of the equipment selected, it is also determined by ease of maintenance and maintenance support/performance.

52. Spare parts, until they are needed, constitute unused capital. Shortages of spare parts are thus common in many developing countries, which suffer foreign currency constraints. There are, however, methods available for a systematic assessment of spare part needs at the design stage of the plant. Such an approach ensures that only the correct spare parts will be acquired, and an optimal initial stock of spare parts to cover the first few years of plant operation should be ordered during plant construction. A continuous process to monitor spare part needs and resupply consumed spare parts must be organized. Pooling of spare parts between individual power plants and between companies can decrease the quantity and cost of all needed spare parts.

53. The adequate dimensioning of plant workshops is another important aspect of an integrated approach to maintenance planning. While there are no available general rules for the design of these workshops, factors to be considered in the design include the type of power plant, the mode of operation of the plant (base load or reserve plant), delivery time for spare parts, availability of local workshops, availability of skilled workers, and official regulations regarding welding, pressure vessels etc.

54. When planning for high productivity in power plants, one must balance the use of internal resources against external resources. Traditionally, suppliers provide some staff training in the operation of their equipment. Independent international consulting companies with operating experience from large power plants also offer similar services. The above-mentioned external services may also include a service contract which covers technical support by specialists in various fields, condition evaluation and performance testing, regular inspections and other performance maintenance activities, corrective maintenance, overhauls, resupply of spare parts, site supervision of operation and maintenance, training and feedback of experience from other installations.

55. Sometimes "contracting out" the operation and maintenance wholly or partly to qualified service companies may be economical. The foreign currency needed for external servicing agreements should always be weighed against the probable increase in plant reliability and a corresponding lower need for new power plants with their even larger requirements for foreign exchange.

III. REHABILITATION AND MODERNIZATION OF EXISTING POWER PLANTS AND TRANSMISSION SYSTEMS

56. The normal lifetime of large thermal power plants used to be only 25-30 years, even when the plants were well maintained. Technical innovations made newly built plants much more efficient. However, the situation has changed in recent years in many industrialized countries, mainly because of the difficulty of obtaining authorization to build entirely new plants. Increasing interest is now being shown

in extending the lifetimes of existing plants using modern rehabilitation techniques. Lifespans of 50-60 years for thermal power plants are therefore not unusual.

57. Site-specific hydro power installations that become outdated are routinely replaced with new plant and equipment. Rehabilitation of old hydro plants is therefore nothing new, but its importance has grown with the increasing number and size of old plants. A 50-75-year lifetime is not uncommon in countries where hydro development started early this century.

58. The extension of plant lifetimes is not the only reason for rehabilitating and modernizing power plants. Equally important reasons are to increase plant availability, capacity and efficiency; to decrease operating and maintenance costs; to change the fuel utilized; and to minimize adverse environmental impacts. The need for rehabilitation depends on the condition of the existing plant and therefore on how well the plant has been maintained. Many power plants in developing countries suffer from deteriorating performance and low availability due to factors such as rapid growth in electricity demand, which makes maintenance shutdowns difficult, lack of needed finance and lack of skilled personnel and management.

59. Rehabilitation means that practically all the equipment as well as the building and other structures are examined and possibly modernized or substituted. The whole plant or unit is taken out of service during the rehabilitation process, which may vary from 6-24 months. The need of rehabilitation is usually determined by:

- (a) Decreasing availability;
- (b) Decreasing efficiency;
- (c) Decreasing staff safety;
- (d) Increasing failure rates;
- (e) Increasing maintenance costs;
- (f) Increasing risk of complete breakdown.

60. The decision to rehabilitate a power plant or a generating unit is taken on the basis of a feasibility study, which is compared to other alternatives for increasing the generating capability of the company.

61. Rehabilitating an existing plant or generating unit is often more difficult than constructing a new plant. It requires a detailed investigation by the companies' own experts or by an outside consulting company. Close co-operation with plant management and contacts with key component manufacturers are essential throughout the study. The technical status of plant or generating equipment has to be determined and the reason for poor performance identified; this is done through inspections, testing of vital components, analysis of operational records and discussions with the responsible operating and maintenance staff.

62. Having established the technical status of the project, a decision has to be taken on the main goal of rehabilitation, taking into account the physical plant and long-term needs. This decision would broadly determine the future mode of plant operation, the desired available capacity, the fuel or fuels to be used, the expected efficiency and the lifespan prior to the next major rehabilitation or complete shut-down of the plant or generating units.

63. The investigation must estimate the availability of the generating unit after rehabilitation. This can be done using the previously described RAM technique. To obtain the desired availability, it may be necessary to improve design quality or redundancy of major components and systems. The upgrading of generating units may require logistical support beyond the present capabilities of the plant's operation and maintenance organization. Rehabilitation then must include a study of the needed future operation and maintenance organization and consequent staff training.

64. For the detailed design of many of the main components, life-cycle cost calculations are most useful. Cost calculations cannot be as exact as for new plants, since uncertainties on the exact status of thousands of technical components will arise. Detailed cost benefit analysis can only be implemented through the power development programme established for the plant. Based on the result of these calculations, plant management must decide on the best approach to rehabilitation and the appropriate time schedule.

65. The detailed rehabilitation plan should describe all activities to be performed, including required material, staff and financial resources. Experience from rehabilitation projects carried out in developing countries shows, that significant problems may arise for any of the following reasons:

- (a) Rehabilitation work is technically difficult and non-glamorous;
- (b) The exact magnitude of the work to be done is sometimes difficult to assess during the planning process;
- (c) Most work has to be done locally, and there may be a shortage of qualified technicians;
- (d) Since work completion time estimates require wide margins, a flexible work schedule is needed;
- (e) The cost/benefit analysis has a significant margin of uncertainty;
- (f) Unforeseen extra physical reinforcements and other expenditures may necessitate changes in the work programme;
- (g) The power system may not allow extended unit outages to complete all the work during one period;
- (h) The rehabilitation budget may limit the amount of work that can be performed in each calendar year.

66. To implement the rehabilitation project, it is preferable to set up a special project management organization with overall responsibility. The personnel assigned to the organization might come from various departments in the company and/or from outside contractors. Participation of local staff in the rehabilitation work should be significant, since on-the-job training will increase staff ability to conduct future operations and maintenance tasks.

67. The extent of outside resources necessary for the rehabilitation project depends upon the available expertise within the company. Due to the many project uncertainties, experience shows that a contract with an external contractor should do the following:

(a) Identify the risks, and divide them between the plant owner and the contractor in an acceptable manner;

(b) Specify work goals/targets and not overly specific ways and means;

(c) Prepare a Memorandum of Understanding in addition to the contract to clarify the thinking behind the contract and help resolve potential conflicts during the work programme;

(d) Guarantee the contractor a profit that matches the risks assumed.

68. The many rehabilitation projects being implemented world wide show the importance of rehabilitation as a means of rapidly and economically adding generating capacity to the power system. In general, hydro plants are less complicated than thermal power plants and therefore easier to maintain. Carefully designed maintenance systems for hydro plants are already in operation in several developing countries, and the results have been good availability and up to 25 years or more operating time before needed major rehabilitation. Rehabilitation plans in Bolivia, Colombia, Jamaica and the Sudan, for example, are increasing available capacity and raising efficiency. For thermal power plants, higher reliability, availability and safety and lower expenses have been attained by effective planning and maintenance, resulting in increased plant revenue.

69. Presentations made at recent United Nations seminars have shown that the costs per kW of rehabilitated capacity may be one fourth the costs for the same capacity in a completely new plant. The implementation time is also significantly shorter for the rehabilitation alternative. To safeguard the results achieved through rehabilitation, it is necessary to raise funds for the continued proper operation and maintenance of the plant during its expected new lifetime. In addition, skilled and dedicated personnel must be made available through continued training programmes. Only in this way can the efficient use of invested capital be guaranteed.

70. Transmission and distribution installations are components of well integrated power systems. Individual transmission lines and substations will from time to time need intensive overhaul or complete rehabilitation. The lifetime of high voltage transmission lines can, through rehabilitation, be extended to 60-70 years or more, assuming moderate climatic conditions. Equipment in transmission

substations, however, has a considerably shorter lifespan. Transformers, and especially breakers and control equipment, may thus have to be completely replaced after 25-30 years, if not sooner, by modern and more reliable equipment.

71. The transfer capability of transmission systems is determined by the combined interaction of all components. By introducing new components to the system, the transfer capability on transmission lines can be substantially increased. This is the case when the transfer capability is limited by stability or voltage control constraints. The stability limit can be increased by decreasing the reactance of generators and transformers, by installing series capacitors, by improving generator control and the relay protection system, and by introducing static VAR compensators.

72. Most of the above-named methods have been utilized for many years. The static VAR compensator installations are, on the other hand, relatively new components and have been shown to be very cost-effective. The combination of thyristor controlled reactors and thyristor switched capacitors has proved to be an excellent solution, featuring simplicity of design, robustness and high speed response to transient conditions in power systems.

73. Reactive and active power control in large transmission systems and over power exchanges with interconnected power systems can considerably improve the transfer capability and minimize transmission losses. The introduction of high-voltage direct current lines in large transmission systems can substantially reduce transmission losses and increase the transfer capability of an existing AC system. The high-voltage direct current technique also makes possible economic interconnection links between large transmission systems.

74. A centralized supervision and control system gives a total overview of current operations and the momentary status of the power system. This makes possible - especially in combination with an increasing number of controllable components in the system - an overall power flow control scheme, making possible the optimal use of system capability and minimizing losses.

IV. TRANSMISSION AND DISTRIBUTION SYSTEM POWER LOSS REDUCTION PROGRAMMES

75. Losses are unavoidable in the transmission and distribution of electric power. Power losses in developing countries, however, reach unacceptable levels from the technical and economic points of view, with some countries reporting losses in the 27-30 per cent range. The major losses are due to the resistance in lines and transformers. Losses can be reduced when a certain amount of active power is transmitted by:

- (a) Reducing the resistance;
- (b) Reducing the reactive power flow;
- (c) Increasing the system voltage.

76. Since resistance is proportional to the conductor size, losses can be reduced by increasing the conductor size. An optimal conductor section is obtained when the marginal cost of increasing the conductor size equals the marginal value of the decreased losses. The optimal conductor size, consequently, depends on the cost of conductors and the value of power losses. It may thus vary not only between countries but over time. In similar ways, the resistance should be optimized in transformers and reactors. Manufacturers need information on costs associated with losses to produce optional design transformers. This also concerns the no-load (magnetic) losses in these components.

77. Power transfer over transmission and distribution systems usually increases over time. Theoretically, conductor sizes should be continuously increased to maintain optimal values. Since this is obviously not possible, conductor sizes in new transmission and distribution lines are usually chosen to represent the optimal size for a power transfer anticipated some period after taking the system into operation. The technical transfer capability of transmission and distribution systems is usually considerably higher than the optimal current density. The cost of losses, however, increases rapidly with increasing power transfer. It is, therefore, usually economical to change the conductor size before the technical transfer limit is reached.

78. A flow of reactive power over transmission and distribution lines increases the current and thus the losses. It is therefore economical to reduce the flow of reactive power over the lines by balancing the reactive power - i.e., by controlling the power factor.

79. In distribution systems, the installation of shunt capacitors to reduce the flow of reactive power over the lines has a long history with very good results. Larger capacitors are often equipped with breakers to enable a control of the reactive power balance both for high and low load on the system. In order to control the power factor in deliveries to consumers, most power companies include charges for reactive power in their normal tariffs for large customers. In this way an optimal installation of capacitors between the distribution system of the power company and the internal distribution system owned by large customers can be achieved.

80. On large transmission systems, the control of reactive power is very important, not only from the point of view of losses but also due to the influence of reactive power on voltage regulation and the transfer capability of the system. It is now common practice to keep a fairly constant voltage over the entire system, independent of the transfer of active power. This requires close control of the reactive power balance. Static VAR compensators have consequently become important new components in many transmission systems.

81. Power losses are very sensitive to the system voltage. This is one reason why the voltage on existing transmission systems is usually kept about constant - near the maximum - over the whole system. When designing a new transmission or distribution system, a high voltage is beneficial but raises installation construction costs. In theory, optimal voltage exists when the two factors balance each other. In practice, it is difficult to calculate this optimal voltage, since

the system is dynamic, with a normally continuously growing transfer demand. For a new system with constant power transfer, the optimal system voltage is nearly proportional to the square root of the power transfer. This formula indicates the need to introduce a higher system voltage when the power transfer increases considerably.

82. The cost of losses is often higher than anticipated. In optimal design systems, both in regard to conductor sizes and system voltage, losses equal about one third of total transmission or distribution costs. With increasing power transfer above the optimal current density, the cost of losses increases rapidly. At twice that current, losses account for almost two thirds of total transmission costs, while specific transmission costs remain constant. With further increase of the power transfer on the same system, specific transmission costs start to increase, but the cost of losses still dominates. If, on the other hand, it is possible to increase conductor size in proportion to the transfer load, specific transmission costs would decrease while the cost of losses would slowly increase.

83. This shows the importance of not loading transmission lines much above the economically mandated current density. If conductor sizes cannot be increased, new lines have to be built, and at some point a new transmission system has to be superimposed on the existing one. The total power lost in transmission and distribution systems naturally depends on the length of those lines. Within a defined region, line lengths are approximately determined by the load density. In optimally designed systems, total losses as a percentage of total load will decrease with increasing load density.

84. The law of decreasing specific losses is the main reason why the percentage losses on transmission and distribution systems are considerably lower in industrial countries - around 8 per cent of total generation - than in developing countries - 20 per cent or higher in many cases. This fact is often overlooked when the fairly high generation losses in developing countries are described.

85. When losses in transmission and/or distribution systems become too large, they seriously threaten the well-being of the utility. It may then be necessary to initiate a total "power loss reduction programme". The key component part of such a programme is to check that current densities on lines are not much higher than optimal values. If such is the case, the lines should be rebuilt with larger conductor areas. If this is not possible, new lines have to be built. In the long run it will be necessary to superimpose a new system with higher system voltage on the existing one. It is important, in an existing system, to check the flow of reactive power and possibly install new reactive power components, such as static capacitors and/or static VAR compensators. Those same components may be used to control the voltage on the system.

86. In many developing countries, the difference between total generation and total sales may be substantially higher than can be explained by technical losses on the transmission and distribution systems. The remaining difference is due to so-called non-technical losses. There are at least two different explanations for such losses. The most common may be that consumers do not pay their bills and the

corresponding sales are not recorded in the statistics. This has at first to be remedied by compilation of electricity sales statistics and recording of all unpaid bills. Then, methods have to be introduced by which a better payment system is enforced. Another explanation of non-technical loss is fraud. Consumers steal electricity either by disconnecting the electricity metre or by connecting to the distribution lines. Such installations are not only illegal but dangerous for the people using the electricity. The remedy is periodic inspection of the distribution system and better control of customer installations.

V. TECHNICAL AND ECONOMIC ADVANTAGES OF REGIONAL POWER SYSTEM INTERCONNECTIONS

87. Electricity supply systems are continuously growing to meet the ever-increasing demand for electricity. Many small isolated systems have successively been coupled together to form large interconnected systems with high efficiency and low generating costs. International borders do not limit these interconnected systems since there are several examples of international grid systems. The growth in power interconnections follows directly from the advantages of lower overall generating costs, lower overall reserve capacity and higher security of supply.

88. To attain minimum generating costs, a power supply system should be operated according to the short-run marginal cost principle. Simply stated, that means that units are operated according to their variable, or running, costs. Units with low variable costs (e.g., thermal power plants with low fuel costs and high efficiency) are operated during most of the year as base load plants. Units with higher variable costs (e.g., gas turbines with high fuel costs) are only operated during peak load periods. In this way, minimum overall generating costs on the system are achieved while fuel is economized and environmental impacts, mainly in the form of air pollution, are minimized. The principle is also valid in hydro and mixed hydro/thermal power systems. The variable costs of hydro plants are mainly determined by the "water value" in their upstream reservoirs. For run-of-stream hydro plants, there is no water value, and the variable costs of the plants are very low.

89. Interconnections of national power systems to large interconnected systems mean that overall generating costs can be further decreased by power exchanges between countries. Those with low short-run marginal cost export power to countries and utilities having higher short-run marginal cost values. For instance, hydropower from one country could replace expensive thermal power in another country. The savings and the corresponding environmental improvements are often considerable; on the Nordic power system grid, they amount to hundreds of millions of dollars.

90. Total capacity on a power system should include a certain reserve capacity above the expected maximum peak load to allow for maintenance, disturbances etc. The level of reserve capacity depends on the required security of supply. It will be high if the system contains only a few, large generating units which contribute significantly to maximum peak load on the system. As a rule of thumb, it is

sometimes stated that the size of the largest unit should not be larger than 10 per cent of the maximum peak load.

91. By interconnecting two or several power systems, relative reserve capacity can be decreased without diminishing the security of supply on the individual systems. If one generating unit or plant trips out of service in one country, power is instantaneously imported from neighbouring systems, and consumers will not be affected. Regional interconnections thus allow individual member countries the ability to decrease their reserve capacity needs. It also makes it possible - especially when interconnecting small power systems - to build larger and more economic generating units.

VI. FINANCIAL AND INSTITUTIONAL ASPECTS OF ENERGY SAVING STRATEGIES IN THE POWER SECTOR

92. Developing countries vary substantially in size and level of development. Installed capacity in China, India and Brazil is over 50,000 MW, while it is only a few hundred MW in several smaller countries. The relative costs for hydro and thermal power plants have already been discussed. Estimates of capital expenditures for electric power in developing countries during the 1990s can be made using the expansion plans of electric utilities. World Bank estimates indicate that, for developing countries in general, capital expenditures will amount to roughly \$450 billion for generating capacity, \$80 billion for transmission lines, and \$150 billion for distribution networks. Of total capital expenditures, approximately 40 per cent will be financed through foreign technical co-operation.

93. Two thirds of all capital expenditures for new generating capacity are scheduled for Asia and are dominated by China and India. Plans indicate that only 1.5 per cent of new capacity expenditures will take place in Africa. Coal and hydropower will continue to be the dominant sources for power supply.

94. Given the size of planned capacity expansions, the expected peak loads, and the estimates of capital expenditures, the average capital expenditure for additional system capacity in the 1990s will be \$1,940 per kW. This is a conservative estimate, which could easily rise to \$2,500 per kW.

95. Utility expansion plans indicate that developing countries intend to double their generating capacity in the next 10 years. The magnitude of this expansion dictates that renewable energy sources such as photovoltaics, wind energy, geothermal and mini-hydro will have little impact in the overall scheme. While it can be argued that these expansion plans are unrealistic, given current levels of power sector lending, still, they represent the targets of Governments and utilities in fostering general economic development.

96. Costs for rehabilitation and modernization of power plants vary, depending on the energy source employed and the scale of the project. However it is not uncommon for costs to be between 10 and 25 per cent of the costs required for construction of new generating capacity. Such savings are now being looked at

favourably by lending agencies, and as a result their lending policies are now slowly starting to favour rehabilitation projects. More needs to be done, however, to accord power plant modernization and rehabilitation even greater priority in the loan programmes of these lending bodies.

97. There are many reasons for the low productivity in the power sector in many developing countries. Public enterprises in these countries often demonstrate poor, unreliable performance and low efficiency. Greater stress should be placed on improving incentives for enhanced utility efficiency and giving greater emphasis to rehabilitation and maintenance and to sector restructuring and institutional reforms.

98. Over the past 20 years, according to World Bank reports, the overall performance of the majority of publicly owned electric utility companies in developing countries has steadily deteriorated. Key contributing elements are lack of financial resources, poor management, inefficient operational procedures and a pervasive lack of maintenance.

99. Inefficient operational performance is not just the outcome of easily observable external factors or deficiencies but rather the consequence of a set of institutional and human constraints, both within and outside the organizations affected. There are economic, financial, political, institutional and legal factors which effect the selection and retention of management and staff. There is need for policy and management reform packages designed:

(a) To remove the human/institutional bottlenecks that keep the performance of publicly owned companies at low levels;

(b) To provide the companies with more efficient incentive and management schemes;

(c) To provide state-owned companies with technically capable management.

100. Power supply companies in many developing countries continue to plan for large capital expenditures for new plant construction. At the same time it is clear that the power supply industry has been favoured by most Governments in the past and has obtained a significant proportion of the limited available financial resources in these countries.

101. Against this background, it is interesting to note that electricity is today heavily subsidized in many developing countries. The reasons are varied and include support to the productive sectors of the economy and as a spur to rural electrification. Such a policy in the long run, however, defeats its own objectives, since low energy prices promote wasteful procedures. Energy prices, as a rule, should pay for the resources and capital used in the energy supply process, and give energy consumers a clear message on actual costs and economic value. Realistic electricity pricing would also help utilities attract the necessary capital to finance new projects.

102. The growing utilization of energy world wide has had an impact on the environment, and the power sector has and is contributing to the problem. The

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environmental impact of power plants can be local, regional or even global in character. Although they all have to be carefully assessed, the global impact has emerged during the past few years as perhaps the most critical issue. This is especially the case with the emission of carbon dioxide which contributes to the so-called greenhouse effect, which could result in severe climatic disturbances in the future.

103. The main way to reduce carbon dioxide emissions from power plants is to reduce fossil fuel burning. In industrialized countries having adequate technical capability and infrastructure, power plants utilizing fuels and processes that contribute less to the greenhouse effect should be used to a greater extent. For developing countries, hydropower is the best option where such resources are available. Regional co-operation for developing hydropower may be possible in some parts of the world.

104. In many developing countries fossil fuel power plants are still the only option for new power plant construction. While improved operation and maintenance will help these plants reduce the resulting environmental effects, these countries often face extreme difficulties in financing the extra investments needed to decrease the environmental effects caused by emissions of sulphur oxides and nitrous gases, dust, hot cooling water etc. New mechanisms for international financing of these investments are required.

105. Development banks and bilateral assistance institutions have played and continue to play an important role in financing the necessary investments in the power supply industry of developing countries. So far these institutions have usually favoured investments in new power plants. By investing in improved operation and maintenance of existing power plants and in the rehabilitation of older plants, overall productivity will increase at far lower cost, compared to the option of constructing new plants. This is a critically needed re-direction in the investment policy of the international financing institutions. Many such projects have already been successfully implemented. It is, however, necessary that both development banks and bilateral assistance institutions adopt decisions in principle to direct some of their funds away from investments in new power plants and towards cost-effective investments in the maintenance and rehabilitation of existing plant and equipment.

106. The efficient operation and maintenance of power systems and installations can only be achieved by qualified staff. To meet this objective, power companies in developing countries have to commit themselves to an adequate staff development programme which comprises training and other activities. Since training in a long-term activity, it often competes with short-term technical and economic issues for limited financial and human resources. Corporate management support is therefore essential:

(a) To formulate the training policy, comprising objectives, organization and levels of ambition;

(b) To create the conditions for training - i.e., staff, facilities, scope and rewards;

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(c) To initiate, follow-up on and promote the different training activities, which require planning, implementation and management involvement.

107. An adequate training programme is fairly expensive. The relationship between investment in training and company profits are not straightforward. The profits come from higher plant availability and lower costs for corrective maintenance and rehabilitation. Training is needed not only in connection with commissioning new power plants but also as repetitive training for existing personnel. In many countries, the status of training needs to be improved; formal requirements for training may be considered a condition for promotion to higher and better paid positions.

108. Although the optimal level of training costs depends on individual circumstances, some international guidelines are useful. A rule of thumb is that at least 1 per cent of the total investment for a new power plant should be reserved for training of staff in plant operation and maintenance. Another such rule might be that about 5 per cent of the annual working hours in an organization should be reserved for repetitive training.

109. When considering an optimal training programme, the following points are of special importance:

(a) A training programme should be derived from an analysis of the organization performing the work - e.g., what education and experience should be required for the different positions;

(b) Formal courses must emphasize the connection between theory and applications. The design of such training courses requires an understanding of job requirements and practical job experience; otherwise, it may tend to be nothing but a formality;

(c) It is preferable to spread out the learning period in order to increase the interaction between theory and practical experience;

(d) Learning a job is only partly accomplished through formal training; full mastery is attained as an integral part of actual work. Therefore, conditions for learning which are integrated with or parallel to regular work must be created;

(e) After going through formal courses, trainees have to progress further by repetitive training and individual career plans.

VII. RECOMMENDATIONS

110. The Committee on Natural Resources may wish to consider the following recommendations:

(a) The United Nations is urged to enhance its activities in energy conservation, power-loss reduction and power plant rehabilitation programmes. Improving the efficiency of existing electric power facilities is a cost-effective method for developing countries to reduce energy costs, stretch their energy supply

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base without heavy sectoral investment, save foreign exchange, and protect the environment. Systematic operation and maintenance procedures can significantly increase efficiency, while life-cycle cost investment planning should be utilized to promote power plant modernization and rehabilitation;

(b) International and regional financing institutions and bilateral assistance agencies should accord high priority consideration to the cost-effective modernization and rehabilitation of existing power generation capacity before approving new plant construction. In this respect, the Committee on Natural Resources may wish to support the Energy Conservation Multi-Agency Group initiative which comprises multilateral, bilateral and private sector organizations and whose purpose is to promote and facilitate energy conservation and power system rehabilitation in developing countries;

(c) Developing country Governments should give due priority to energy conservation and power system rehabilitation policies.



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ENERGY RESOURCES

Technical co-operation programmes on the exploration,
development and efficient use of energy resources

Report of the Secretary-General

SUMMARY

The Economic and Social Council by its resolution 1989/6 requested the Secretary-General to prepare a report on the question of technical co-operation in energy. The present report, in response to the request, first identifies the priorities for technical co-operation programmes in the early 1990s as specified by developing countries. It then outlines the various strategies and modalities for technical assistance which are employed by the Department of Technical Co-operation for Development (United Nations Secretariat) to respond to those priorities. Lastly, an overview of all the technical co-operation activities of the Department is presented, including projects, international meetings, publications and software.

* E/C.7/1991/1.

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INTRODUCTION

A. Energy outlook

1. In the next decade energy will continue to be a major factor and possible constraint facing developing countries as they strive to attain their national socio-economic objectives. The demand for energy in developing countries in the 1990s will grow at a faster pace than in industrialized countries. This will be due to population growth, together with the increasingly rapid process of urbanization. The net effect in developing countries will be increased demand for energy and a more pronounced shift from traditional to fossil fuel sources of energy.
2. The majority of energy-deficient developing countries are still expending a large share of their export earnings to pay for energy imports. Reliance on energy imports is, therefore, a continuing burden which depletes foreign exchange earnings which are required for the purchase of capital goods. As a result, a major priority for energy-importing developing countries is to reduce their dependence on energy imports. Where feasible, developing countries are responding to this problem by developing their indigenous energy resources. This activity calls for increased access to investment capital.
3. Lower energy prices have brought about a fundamental re-orientation of energy investments, which may be expected to continue, at least for the medium term. The flow of investment in energy exploration towards developing countries for resource development has been reduced. The capacity for accumulation of capital and access to external financing by energy-importing developing countries has deteriorated. Therefore, the high level of capital investment required for the exploration and exploitation of energy resources continues to be one of the major constraints.
4. On a global scale, the introduction and wide application of advanced energy technologies and research in new technologies fostered by the once-high oil prices has declined. In general, there is a sense of false security created by these lower energy prices in all countries and in organizations funding or providing technical co-operation in this area. As a result, energy development programmes have been allocated a lower priority than in previous years.
5. Another major constraint for self-sustained progress is the inadequate supply of technical personnel in the diverse and numerous specialties needed in the energy sector of developing countries.
6. In recent years, there has been a growing awareness of the close relationship between energy and environmental issues which has opened an entirely new area of international concern. There is need to intensify the monitoring and analysis of environmental aspects, policies and measures of development and use of energy, particularly with regard to issues transcending national boundaries.
7. Finally, in many cases the policies and institutional framework of the energy sector do not present the necessary flexibility for quick adjustment to the

changing and uncertain economic environment of the energy sector. An inadequate information system for national energy policy-making and energy-sector management is an important contributor to the problem.

B. Technical co-operation objectives

8. The experiences of the last decade in technical co-operation have resulted in a redefinition of priorities and objectives for the period 1992-1997. These objectives are in harmony with the medium-term plan of the United Nations for that period and include the following:

(a) Flow of energy-related information to developing countries. A critical priority of developing countries is to increase the flow of technical and economic information needed for self-sustained development of their energy resources and the planning and management of energy sector activities. Another key element in strengthening the energy sector is the establishment of energy information systems for energy planning and energy sector management. An adequate information system is not only a necessary tool for effective policy-making and management; it also serves as an institutional memory;

(b) Development of indigenous energy resources. A systematic assessment of indigenous energy resources is a necessity for the majority of the energy-importing developing countries in order to increase the share of energy supplied from resource endowments, thereby striving towards energy self-sufficiency. To achieve this goal, expanded energy survey, assessment and exploration activities need to be undertaken to identify, locate and evaluate the development potential of conventional and new and renewable sources of energy. In view of the high risk and cost of energy exploration, there is further need to attract the requisite financing and to improve access on the part of developing countries to existing financial sources;

(c) More efficient energy utilization in end-use sectors and rehabilitation/modernization of existing energy sector infrastructure. It is critical that energy conservation and efficiency programmes be developed and implemented, since they are far less expensive than new, capital-intensive energy supply projects. They also have a beneficial effect on the environment through lower pollution per unit of output. For the same reason resources should be preferentially allocated to the rehabilitation and upgrading of aging infrastructure for the generation and transmission of energy;

(d) Development of human resources. Staff training programmes in the energy sector should concentrate on increasing the supply of technical personnel at all levels, including managers, engineers, operators and maintenance staff to address the continuing critical shortage of trained staff. Improvement of living conditions and remuneration may then attract personnel to remain in governmental service in the energy sector;

(e) Institution strengthening. The structural changes which have occurred in the world energy market necessitate a re-evaluation and strengthening of the institutional framework in the energy sector. The role and organization of state

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energy enterprises and institutions need to be adjusted to achieve greater efficiency, either directly or through private-sector involvement. Internal energy price structures need to be reviewed in order to ensure accumulation of capital for investment and economically sound performance of the energy enterprises. Legislation and model contracts need to be reconsidered in order to establish a proper balance between the long-term objectives and policies of a country and the need to attract investment capital to the energy sector;

(f) Energy and environment. In view of the impact of energy on the environment, increased emphasis is being given to assessment of that impact at the stage of energy programme and project design specifically to remedy environmental problems caused by energy production, transport and consumption activities.

I. STRATEGIES FOR TECHNICAL CO-OPERATION IN ENERGY

A. Creation of self-sustaining and lasting capacities in recipient developing countries

9. The basic approach to technical co-operation as identified by developing countries is the provision of the tools, training and information required to permit them to make and implement energy policy decisions related to economic and social development. The objective of such assistance is to develop the capabilities of national experts and institutions so that development efforts become self-sustaining and continuous.

10. The Department of Technical Co-operation for Development of the United Nations Secretariat has found the pre-condition of most successful technical co-operation to be the establishment of a project team consisting of national professionals and a few selected international experts. The team then jointly addresses a specific problem of pressing importance to the country, and the national counterparts acquire the skills required for future work.

11. This method is preferable to the approach of solving the problem for the country based on the use of external expertise only. It may, in the short term, appear slow or inefficient; but in the long run, it has a more lasting effect and impact on the recipient country. Special cases do exist which require other methods of co-operation, such as problems that must be dealt with on an emergency basis or complex undertakings where sub-contracting the tasks to consultant firms is more appropriate. But in general, the formula of a national team supported by international experts, recruited individually or from consulting firms, gives the best results.

12. One key result of this type of co-operation is that it permits the creation of basic capability in the developing country properly to address problems in the energy sector. This increased knowledge and understanding allows national experts better to assess their country's needs and thus better negotiate with international assistance organizations and financing institutions. Negotiations carried out by well informed parties will result in agreements by which all sides can gain. And indeed, in the end, only this kind of agreement will be honoured by all parties and yield desired results.

B. Training and the transfer of technology

13. At the request of recipient countries, priority is given in technical co-operation activities to the training of national experts and to the provision of state-of-the-art, proved technologies. The energy sector is, in general, technology intensive; and United Nations technical co-operation projects reflect this condition.

14. One successful example is the establishment of a permanent interregional training centre for energy studies at the headquarters of the Latin American Energy Organization (OLADE). The United Nations/OLADE Training Centre is fully equipped with microcomputers and projection systems to assist in all types of presentation and software demonstration. It offers courses in Spanish, English and French. Participants from Africa, Latin America and the Caribbean have received training at the Centre. To date, course material has focused on energy information systems and energy modelling tools. A trio of software applications developed by the Department of Technical Co-operation for Development are used as training tools for energy planners (see para. 96).

15. Other short-term and long-term training programmes in energy planning are focusing on other regions. In Africa, lecturers are being trained and university programmes are being developed in energy planning and management to address the recurring shortage of national professionals. The Department is also co-operating with the World Bank by providing lecturers to regional seminars on energy policy analysis. In Asia, the Department has been active in organizing training courses in energy planning and planning software under the Regional Energy Development Programme of the United Nations Development Programme (UNDP).

16. In the petroleum sector, training centres are being established for oil exploration and development techniques, sand control, reservoir studies and petroleum engineering. Courses are offered in abnormal pressure detection, well control, well planning, computer-aided drilling, directional drilling, enhanced oil recovery, petroleum engineering and petroleum exploration. In related training activities, national teaching staff are being placed in advanced training courses in gas technology, corrosion engineering, off-shore drilling, petroleum geology, training management, petroleum administration and accounting.

17. In the power sector, specialized training programmes are offered in the efficient operation of large integrated power networks, including such fields as utility management and operation, thermal and hydropower generation, distribution engineering, and commercial aspects of electricity supply. Permanent training workshops are being established for the maintenance personnel of both diesel and hydropower plants. Moreover, training programmes are being developed at universities for power sector engineers in the least developed countries where urgent needs exist for technical expertise.

18. Research and development centres for new and renewable sources of energy are being established:

(a) To study and adapt solar energy equipment and solar building designs for use domestically;

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(b) For local production, on a pilot basis, of cost-effective solar energy appliances for space heating, water heating, cooking, fruit drying and other uses;

(c) To organize public information programmes for mass education on the potential and use of solar energy appliances.

In addition, they provide training in advanced techniques for active and passive solar heating and cooling and in equipment operation.

C. Information flows in the energy sector

19. In the process of making energy decisions, several issues have to be addressed and each has specific data requirements. These issues include: energy pricing, energy investment, energy research, development and demonstration, emergency planning, energy system management, long-term energy planning, and development strategies. The data requirements include information on energy demand, energy resources, energy conversion and energy technologies.

20. Information on both the international and domestic energy market is critical for many developing countries. Therefore monitoring systems are extremely important for providing reliable data on prices, patterns of energy supply, marketing and distribution, conversion and end-use, and state-of-the-art technologies. Taking the case of the vital petroleum sub-sector, such information might include ex-refinery prices, ocean transportation and insurance charges on a product-by-product basis to various destinations, and marketing margins. This information would be essential for energy-sector management and decision-making and would help to identify opportunities for minimizing foreign exchange costs through conservation and/or substitution of hydrocarbon resources with available renewable sources of energy. Information on the energy sector is key to successful negotiations with petroleum-importing, -marketing, and -distribution entities.

21. Developing countries realize the growing importance of information and are asking the Department of Technical Co-operation for Development to assist them in the establishment or strengthening of national energy information systems. Such information systems are useful in organizing data, identifying gaps in information, permitting in-depth analysis of the energy sector and responding rapidly to reporting requirements. Projects in this area focus on the delivery of hardware, software, training and information management services.

D. Short-term advisory services

22. At the request of developing countries, the Department of Technical Co-operation for Development provides the services of its interregional advisers, technical advisers, economic affairs officers and international consultants to assist them through short-term advisory missions. These experts, highly qualified and experienced in all major aspects of energy development (oil, coal, gas, electric power, energy policy and planning, conservation, geothermal, solar, wind, microcomputer software programmes), provide advice on energy policy, resource evaluation and exploration, design of projects and feasibility studies. The

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missions are unrelated to projects and are funded under the United Nations Regular Programme of Technical Co-operation at no cost to the requesting country. During 1989, 33 advisory missions were undertaken at the request of United Nations Member States.

E. Trends in technical co-operation in energy

23. A recent trend in international technical co-operation is the designation of a Government-executed projects. At the request of Governments, the Department is assisting in project execution by undertaking a new form of technical co-operation - the provision of management services. Management service agreements permit the Department to execute components of large bilateral or multilateral aid programmes. Such management services can take many forms - from the provision of experts, equipment or contractual services, to the overall management of an aid programme. The Department is finding that recipient countries are eager to have the United Nations involved as an impartial, technically capable intermediary. Funding agencies are responding favourably since they see that the presence of the United Nations in a project makes the aid programme more acceptable to developing countries. In addition, the overhead costs for management services may be substantially lower than those typically charged. The costs are negotiated on a case-by-case basis, responding directly to the issue under consideration. This flexibility allows the Department to tailor technical assistance to special needs.

24. Given the recent orientation of technical co-operation along programme lines, countries where energy has been identified as a priority under the country programme are requesting the United Nations to field teams of energy experts. This approach permits a comprehensive and integrated analysis of areas requiring technical advisory services and/or project formulation.

F. Environmental considerations

25. The Department of Technical Co-operation for Development is responding to the requests of developing countries for assistance in addressing environmental problems resulting from the energy sector. The combustion of fossil fuels has had various environmental effects. Gaseous, liquid and solid emissions have, in large part, contributed to the "greenhouse effect", urban industrial air pollution (smog) and the increasing production of acid rain, resulting in the acidification of lakes and the destruction of forests. The growing fuelwood scarcity in developing countries is leading to further desertification and greater reliance on fossil fuels. The risk of nuclear reactor accidents and waste disposal problems have slowed nuclear power programmes. It is generally agreed that the next two decades will witness a transition to a more efficient, less polluting energy mix, utilizing to a greater extent "cleaner", new and renewable energy sources.

26. Environmental concerns included in technical co-operation projects include: more efficient fossil fuel production, transport and utilization operations; lower emissions from fossil-fuel-burning electric power plants; environmentally safer coal-mining activities; re-injection into reservoirs or safe disposal of geothermal fluids; socio-economic impact analysis for small hydropower plants to ensure that

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adverse environmental impacts are minimized; implementation of new and renewable energy demonstration projects to reduce the speed of deforestation.

27. In the energy sector, environmental concerns have always been a concern at the project design stage. But a new development has been the formulation of projects specifically targeting improvement of the environment. A project in China is modernizing a pilot coal-fired power plant, reducing coal consumption while raising power output, thereby reducing emissions. It is a pilot project for 112 other power plants of similar design. Another project, in Kenya, will assess the environmental impact that the future development and exploitation of geothermal resources may have on the Olongai-Solai and Hell's Gate-Longonot areas of the Kenya Rift Valley.

II. OVERVIEW OF TECHNICAL CO-OPERATION PROJECTS CARRIED OUT BY THE DEPARTMENT OF TECHNICAL CO-OPERATION FOR DEVELOPMENT IN THE ENERGY SECTOR

28. The Department of Technical Co-operation for Development is currently executing 117 projects in the natural resources and energy field in 47 developing countries, with total project budgets of roughly \$115 million. While its programme is thus quite large, it is relatively small in view of the needs of the developing countries. The projects do, however, play an important catalytic role in many developing countries, especially at an early stage of their energy development effort.

29. Project activities in the area of energy centre on institution-building through direct support, training and provision of modern equipment. Typical projects may support a governmental program through the provision of long- or short-term international experts; the training of national professionals through brief study tours or longer fellowships to institutions of higher learning; the acquisition of state-of-the-art technologies, whether they be in the form of computers or other equipment specific to an energy subsector; and the provision of contractual services.

30. The examples of ongoing and recently completed project activities presented below indicate the wide range of assistance offered by the Department in the energy field and are grouped under major areas of activity.

A. Energy policy, planning and conservation

31. The continuing energy demand/supply imbalances in many developing countries have encouraged Governments to establish and/or strengthen their national energy planning capabilities and energy data and information processing capabilities. Some recent Department-executed projects are described below.

32. Assistance is being provided in the formulation of energy master plans and comprehensive energy resource surveys and in the analysis of energy resource development and utilization, fuel sub-sector analyses, and rural energy surveys. The capabilities of energy planning departments are being strengthened through the introduction of energy information systems and computer modelling packages,

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training of staff and upgrading of computer facilities. Such assistance in planning is being rendered in Bangladesh, Ethiopia, Ghana, Jamaica, and Vanuatu.

33. Regional and international expertise is being shared under a project with the Latin American Energy Organization (OLADE) through the fielding of experts providing advisory services in energy balances, energy pricing, financing of the power sector, petroleum sector management, energy conservation, and rural household energy studies.

34. The Department is playing an instrumental role in the establishment of regional training centres for energy studies, such as the United Nations OLADE Training Centre, and is continuing to develop microcomputer software packages for use as training tools in workshops. This activity necessitates close co-operation with regional institutions and has succeeded in promoting new, concrete examples of South/South co-operation in training junior to mid-level energy planners in developing regions.

1. Energy efficiency and conservation

35. Developing countries have come to realize the significant potential of energy conservation and substitution, both in reducing energy inputs and costs and as a complement to enhanced energy production. To date, projects have addressed energy conservation in the electric power, industry, transport and residential/commercial sectors. Energy cost savings have been identified, totalling millions of dollars and the potential reduction of demand for petroleum products is on the order of 20-30 per cent.

36. With regard to the power sector, the Department is providing assistance to Bangladesh, Iran (Islamic Republic of) and Mozambique in the development of guidelines to cut power losses due to technical and non-technical factors, in the preparation of design criteria for system planning, in reviewing construction details, in identifying high power loss areas, in the preparation of proposals for system rehabilitation, and in the preparation of an action programme to remedy each specific problem. A key element of the programme is the modernization and rehabilitation of older, inefficient fossil-fuel-burning power plants.

37. A training institution for thermal power plant operators is being established in China with the provision of a thermal power plant simulator, introducing trainees to systematic maintenance procedures and improved operation routines to increase power system reliability and availability.

38. In the industrial, transport, residential/commercial and rural sectors, comprehensive national energy conservation programmes are being launched in India and Peru, providing energy auditing equipment, conducting detailed energy audits of industrial enterprises, transport fleets and residential and commercial buildings. In India, energy buses have been designed and manufactured domestically to facilitate regional scale energy conservation programmes. The designation of national lead agencies and the teaming of international and national experts will ensure effective transfer of technology and a self-sustaining capability to maintain energy conservation programmes. The establishment and/or strengthening of

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national institutions for the direction of national energy conservation policies and programmes and for the implementation of energy audits across all sectors is a key element in the success of these programmes.

39. The modernization of a 200-MW coal-fired generating plant is under way in China and will serve as a pilot for the modernization of 112 power stations of similar design. Improvements in the combustion process and in coal handling at all such plants could result in the reduction of national coal requirements by 500,000 tons/year and save 2,240 MW of additional electricity-generating capacity that would otherwise have to be constructed at a capital cost of over \$238 million.

B. Petroleum, natural gas and coal

1. Oil and gas

40. Oil and gas account for two thirds of total developing country commercial energy consumption. While many developing countries remain significantly unexplored or underexplored, some estimates indicate that a significant share of the world's undiscovered oil and gas resources may be found within their boundaries. A key priority of many developing countries is technical co-operation so as to strengthen their technical, institutional and human resource capacities in order to develop their indigenous oil and gas potential.

41. In China, a training centre is being established for oil exploration and development techniques through the provision of modern teaching facilities and advanced laboratories. The centre offers courses in abnormal pressure detection, well control, well planning, computer-aided drilling and directional drilling.

42. Assistance is being provided to China in the application of reflection seismic methods and geologic interpretation to detect potential subsurface deposits, through the provision of modern seismic equipment, including large vibrators and digital recording laboratories. National experts are being trained in advanced geophysical prospecting techniques in marine carbonate basins.

43. State-of-the-art geotechnical equipment as a side scan sonar-tow and marine streamer are being delivered to provide geological and civil engineering data for use in petroleum drilling, oil-field development planning, pipeline laying and related off-shore oil industry activities centring on the Pearl River estuary in China. In India, provision of modern technology includes a complete three-dimensional seismic system, including system installation and commissioning, associated consultancy services, individual training and study tours by staff to examine the operation of similar seismic systems elsewhere.

44. Modern institutes for petroleum exploration, reservoir studies and petroleum technology are being established in India and Turkey to perform primary and applied research in enhanced oil recovery, petroleum engineering and petroleum exploration. In a related training activity, national teaching staff are being placed in advanced training courses in gas technology, corrosion engineering, offshore drilling, petroleum geology, training management, petroleum administration and accounting.

45. Other project activities are formulating petroleum exploration strategies, including off-shore and on-shore seismic surveys by geophysical contractors, preparation of seismic data packages for sale to energy corporations, and formulation of appropriate petroleum legislation, model contracts for exploration and development, and fiscal codes. Assistance is also being provided in producing heavy oil from tapped and untapped reservoirs and in developing suitable methods of enhanced oil recovery. Lastly, modern equipment is being provided to laboratories to conduct sedimentological, palaeontological and palynological investigation, reservoir engineering, core analysis, and chromatography for analysis of drilling muds, cement and water. Such assistance is being rendered in Indonesia, Iran (Islamic Republic of), Mozambique and Turkey.

2. Investment promotion and legislation

46. Assistance is requested in oil and gas legislation and agreements and in the preparation and evaluation of competitive bidding for licences, permits and contracts. Many developing countries have insufficient experience in undertaking the complex negotiations normally involved in these areas. This, together with the growing governmental role in the development of indigenous petroleum resources, has led the Department to assist over 70 countries in this area since the early 1970s.

47. For instance in Belize, Mozambique and Peru, the Department is active in the preparation of exploration promotion packages and the organization of promotional meetings, which are resulting in several agreements with petroleum contractors. New petroleum codes, petroleum tax regulations and revised petroleum licences are being prepared. In Chad, Department advisors are assisting the Government in the preparation of model agreements, carrying out investment promotion and the negotiation of agreements with major oil companies; additionally, support is being provided in contract auditing and in negotiations for the construction of a pipeline and a refinery. As a related activity, a national seminar was organized in Mozambique on the financial analysis of petroleum agreements.

3. Coal

48. In order to accelerate the development and utilization of indigenous fuels, many developing countries are examining the feasibility of exploiting their indigenous coal resources. At the same time, current coal-producing developing countries are attempting to increase their domestic production so as to reduce reliance on oil imports.

49. An active programme of assistance is continuing in planning the modernization of mines through the preparation of studies on coal-mining processes, on mine planning and design, on mechanization, automation, ventilation and environmental control, on computerization, and on coal processing, mine safety and drainage. A regional project focusing on the introduction of computerized monitoring systems in Eastern Europe in both surface and underground mines succeeded in increasing coal production and productivity and in improving safety conditions in coal mines.

50. The Department is providing assistance to India in the modelling and control of water systems in coal mines by identifying and quantifying the resource parameters and hazard value of water in mining environments, by developing computer software for mathematical modelling, by verifying and optimizing the models under actual conditions, by assessing the environmental impact of large-scale mining, and by specifying remedial measures to restore the environmental balance. In a related activity, assistance is being rendered in the effective utilization of hydrofracturing techniques so as to increase output of hard coal at lower production cost.

51. Similar assistance to India is speeding the adoption of ground control techniques (strata control, subsidence control, mine modelling and rock mechanics) and the establishment of modern testing facilities for the safe installation of winding equipment and flame-proof equipment.

52. South/South co-operation is taking place in Peru as PROCARBON collaborates with the Korean Institute of Energy Resources in technology application and utilization, technical design, economic feasibility, and production of coal briquettes so as to reduce dependence on oil and foster increased coal use in the economy.

C. Electricity

53. Among directly usable energy forms, electricity occupies a special place due to its convenience and versatility of application. This is reflected in the rapid growth of electricity demand and in the progressively greater proportion of primary energy being used for electricity production. Recent requests for assistance from the Department of Technical Co-operation for Development stress the longer-term aspects of planning and training in the power sector in developing countries.

54. After two United Nations international seminars, held in co-operation with the Government of Sweden had called attention to the urgent need for power plant rehabilitation, the Department initiated a global, large-scale power plant modernization (including fuel conversion) and rehabilitation project aimed at increasing the efficiency of power plants, thereby increasing the plants' outputs and operating reliability. Proposals for the launching of this global project have been sent by the Department to 33 developing countries which had expressed interest in this type of assistance.

55. In project activities, priority is being given to specialized training programmes in the efficient operation of large integrated power networks including such fields as utility management and operation, thermal and hydropower generation, distribution engineering, and commercial aspects of electricity supply. Permanent training workshops are being established for maintenance personnel of both diesel and hydropower plants in Bhutan. Training programmes are being held at universities in India for power sector engineers from Nepal, where the needs for technical expertise are critically urgent.

56. Crisis management in the power sector is another form of assistance currently being rendered to the Dominican Republic. It includes emergency generation

restoration, planning, rehabilitation and maintenance of transmission and distribution systems, and reduction of technical and non-technical losses.

57. The establishment of computerized data banks in support of long-term electricity planning objectives is an ongoing effort in Egypt. It includes data collection, processing and dissemination and the provision of hardware and software. Follow-up activities include the development of computerized models for network extension and modernization of electric transmission and distribution systems.

58. In conjunction with its programme of small-scale hydropower site surveys, the Department has collaborated with Ethiopia and the Government of Italy in the design and construction of a 5-MW hydropower plant and the installation of transmission and distribution networks providing links to local load centres.

59. Lastly, in Viet Nam, urgent assistance is being rendered in the reconstruction of power supply systems, including supervision of plant construction and testing, and establishment of operation and maintenance workshops.

D. New and renewable sources of energy

1. Solar energy

60. The potential of solar energy in contributing to developing country energy supply is significant, particularly due to the high levels of solar radiation that many such countries experience. Developing countries are concentrating on appropriate, economically attractive measures that can increase the efficient use of solar energy to meet existing needs.

61. The basic elements of many of the Department of Technical Co-operation for Development projects are the determination of a country's solar energy potential and, on the basis of data so acquired, development of solar thermal concentrating systems capable of providing process heat for industry, agriculture and electricity generation.

62. A renewable energy research and development centre in Afghanistan is being established to study and adapt solar energy equipment and solar building designs for use domestically; for local production, on a pilot basis, of cost-effective solar energy appliances for space heating, water heating, cooking, fruit drying and other uses; and to organize public information programmes for mass education on the potential and use of solar energy appliances.

63. In China, a solar heating and cooling techniques experimental centre is being established to provide training in advanced techniques on passive and active solar heating and cooling and in equipment operation. Subsequently the project will design and develop practical photovoltaic systems based on various climatic conditions.

64. Assistance from the Department also includes support of a Cuban programme for the production of polycrystalline silicon from quartz for utilization as feedstock for obtaining the single-crystal silicon required for the electronics industry.

65. In projects in India, Iraq and Romania, assistance to solar energy programmes is focusing on measurements, tests and the preparation of selective coatings, establishment of a solar energy library, technical training programmes, transfer of solar thermal technologies, and drafting of national standards for the design, performance and testing of solar thermal devices.

2. Wind energy

66. Wind power has been harnessed by mankind since early times and is still used in some developing countries for pumping water. Wind electric-power generation is now possible in regions with favourable wind régimes.

67. Typical wind demonstration projects in China and India include the design and installation of technically advanced wind power stations to obtain practical experience in the operation and characteristics of different types of turbines; to conduct research and development in the integration of these machines into an electrical power system; to provide a modest supply of electrical energy for local needs; and to assist in the design and development of larger wind power systems.

68. The Department is very active in the assessment of the wind energy resources of island countries, such as Cape Verde and Mauritius, through demonstration projects that evaluate the feasibility for wind-powered electricity generation to supply the existing electric power distribution network.

3. Multisource renewable energy projects

69. Some of the largest projects that the Department is currently executing in the renewable energy area involve demonstration projects that package several new and renewable energy sources.

70. Assistance is being provided to island countries like Cape Verde, Maldives and Mauritius in determining the potential for the development and utilization of solar and wind energy for purposes of solar water-heating, photovoltaic electricity generation, grid-connected wind electricity generation and mechanical water pumping.

71. In Mongolia, a model demonstration centre is being established for renewable energy designs for nomadic herdsman and cattle farms in desert zones. Research and design work will use solar, wind and biogas energy to improve the living conditions in fixed winter and summer base-camp operations and to demonstrate models for improved pastures, fodder crop production and animal husbandry systems.

72. Another project features the demonstration of integrated rural energy systems comprising solar photovoltaic and wind in four villages of Pakistan, so as to evaluate the technical, social and economic feasibility of these systems as a solution to the energy needs of villages remote from the central grid.

73. A wide ranging project in the Seychelles includes such activities as the development of a biomass gasifier-engine generator using coconut husks; the

development of a low-cost flat-plate solar water heater suitable for local fabrication; the testing and demonstration of small solar photovoltaic battery chargers, and a small wind charger suitable for areas having a satisfactory wind régime; the setting-up and monitoring of solar and wind data measuring instruments/stations; and the installation of a wind generator of 2-kW capacity in a pilot demonstration project.

4. Small-scale hydropower surveys

74. In many developing countries, hydropower potential was first evaluated when petroleum was under \$5 a barrel and, as a result, many sites were considered uneconomic. At current energy prices, however, many of the same sites can produce electricity by hydropower competitively, thereby helping reduce national dependence on imported oil. Small hydropower installations - in the range of 1 megawatt - are of special interest because of their low investment cost, speed of construction and abundance of potential sites, and they can often be attached to existing dams already being used for other purposes.

75. Under a programme jointly funded by Japan, Norway, Sweden and the United Nations Regular Programme of Technical Co-operation, and with particular emphasis on the least developed countries, the Department is executing 48 surveys of small-scale hydropower resources in developing countries, 41 of which have already been completed (Bangladesh, Benin, Bolivia, Burundi, Cameroon, Central African Republic, Congo, Dominican Republic, Ecuador, Ethiopia, Fiji, Ghana, Guinea, Guyana, Honduras, Indonesia, Jamaica, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Nepal, Nigeria, Papua New Guinea, Paraguay, Peru, Samoa, Sierra Leone, Solomon Islands, Somalia, Sri Lanka, Sudan, Suriname, United Republic of Tanzania, Uruguay, Zambia).

76. These missions are undertaken by teams of electricity supply engineers, hydrologists and hydropower construction engineers who visit each country for three to four weeks and report on the hydropower potential of selected sites. Their reports are then used by Governments to attract support from financing agencies or investment from donors for further development of promising sites.

5. Geothermal energy

77. The Department of Technical Co-operation for Development has played a pioneering role in the development of geothermal energy in developing countries over the past 25 years. The projects undertaken have led to the construction of geothermal-based power plants in several countries. At the request of Governments, the Department provides expertise for basic geoscientific surveys (geology, hydrogeology, geochemistry, geophysics), in exploratory drilling for feasibility studies, and in reservoir engineering and management.

78. This assistance takes the form of strengthening national capabilities to explore and exploit both low- and high-enthalpy geothermal resources. This includes geothermal reconnaissance surveys and subsequent technical advisory services leading to exploration drilling and feasibility studies, geoscientific

investigation, and reservoir and engineering studies of geothermal fields. The execution of geothermal feasibility studies typically involves the drilling of deep exploration wells, analysis of physico-chemical characteristics of geothermal fluids, and project economics.

79. As a result of projects executed by the Department, developing countries such as India, Kenya, Mexico and the Philippines are at present generating electricity from geothermal steam. In many cases the amount of electricity so generated represents an important portion of the total energy consumption within the country.

80. In Bolivia, a \$9 million geothermal feasibility study has recently been completed. Four deep exploration wells were drilled, and all are good producers. The geothermal fluids discharged are already more than sufficient to operate a 5-MW back-pressure turbine which will be installed in 1990. Future development will yield enough steam to power a 25-MW condensing type power plant. Since the project site is in a rural unelectrified region, the production of electricity under the project will have a significant impact on the development prospects of this mineral rich area and on the standard of living of its inhabitants.

81. In China, projects totalling \$17 million have undertaken geothermal exploration, constructed power stations, and implemented district heating systems.

III. INTERNATIONAL MEETINGS, PUBLICATIONS AND SOFTWARE DEVELOPMENT

82. The Department of Technical Co-operation for Development undertakes active programmes involving international meetings, research, publication and software development, all in support of its technical co-operation activities.

A. International meetings

83. Of primary concern to developing countries is promoting the international exchange of experiences in all aspects of energy development, especially between developing countries. In this regard, the Department has organized several meetings, workshops and symposia, in each of which over two dozen developing countries have participated, along with experts from industrialized and centrally planned economies and experts and observers from interested institutions.

1. Energy policy, planning and conservation

84. A United Nations symposium on energy planning in developing countries held in September 1981 in Sweden, explored in depth the problems developing countries face in devising and implementing energy planning strategies and also covered institutional, human resource, data management and financial requirements. A meeting on energy supply management, held in December 1982 in France, examined the evolving energy supply policies and strategies in developing countries and analysed the technical, institutional, and financial aspects involved in their attempts to develop their energy resources. A seminar on energy efficiency and conservation, held in September 1989 in Sweden, assessed, from the economic, technical and policy

viewpoints, the energy conservation experiences to date in the industry, electric power and household sectors in both developing and industrialized countries.

85. In September 1985 at a workshop on microcomputer software applications for energy planning, held in New York, the user-friendly software package developed by the Department for energy planning and analysis - ENERPLAN - was formally released. Regional training courses in microcomputer applications for energy planning were subsequently conducted in Asia (February 1988 and April 1989) and in Latin America (December 1989, May and July 1990), using ENERPLAN as a training tool. The training courses provided planners and policy makers from developing countries with an overview of current developments in microcomputer software applications for energy planning, including energy data analysis, energy balance construction, energy modelling and simulation, and policy analysis.

2. Petroleum, gas and coal

86. International seminars covering such topics as petroleum geology, geochemistry, geophysical methods, marine geological surveys and oilfield development techniques were conducted in December 1989 in China, September 1989 in Norway, June 1989 in the Soviet Union, September 1982 in China, and August 1982 in Norway. They focused on developing country needs in strategic planning, the acquisition of geophysical data, geophysical contracts and quality control, and the processing and interpretation of seismic data. Techniques were discussed in production geology and engineering, enhanced oil recovery, reservoir simulation and production practices in carbonate reservoirs. The seminars also examined the applicability of new technologies and methods to developing countries in terms of economics and practical considerations. Finally they presented the investigative results of surveys for the purpose of disseminating to other developing countries the information and experience gained.

87. Two meetings focusing on state-of-the-art coal-mining technologies were held, in November 1985 in China and, in December 1982 in Australia. They studied economic and commercial arrangements for coal utilization in electricity generation and concluded that development of these new technologies would help coal resource exploitation in developing countries, leading to better utilization of global energy resources.

88. Four seminars were held from 1987 to 1989 on the subject of power plant operation, maintenance, rehabilitation and efficiency, in Sweden, Jordan and the United States. The topics covered included rehabilitation of power systems and plants; operation and maintenance procedures of power system installations; financial and technical trends; environmental factors concerning design, construction, operation and maintenance. Another meeting dealt with financing issues and ways to promote higher priorities for work on improved operation and maintenance procedures, personnel training, co-operation between plant vendors and users, and the feasibility of power exchanges between countries.

89. Several recent meetings have focused on new and renewable sources of energy. One meeting in China reviewed approaches to meeting rural energy needs in the areas of heating and cooling, electric power supply, water pumping, and fuel for cooking,

and familiarized developers and operators of such schemes with the relevant technical and economic considerations involved. A subsequent workshop in the USSR covered overall progress and recent advances in solar heating and cooling technologies and applications, including those suitable for transfer to developing countries, and also reviewed developing country technical co-operation needs in these areas. Another seminar in China examined the costs of major solar technologies, the design of houses and commercial buildings, low-temperature applications, and the direct conversion of solar radiation to electrical energy in solar photovoltaic cells.

90. A colloquium was organized in France to facilitate the exchange of experiences between energy specialists, policy makers and managers in the evaluation of prospects of utilizing small-scale renewable energy sources (mini-hydro, biomass, solar, wind) either individually or combined into "energy packages" to meet basic needs in the areas of heating, cooling, village electric power supply, rural water supply and fuel for cooking. A second, related, meeting examined the technical and economic aspects of planning and the implementation of small-scale hydropower schemes.

91. Finally, a workshop on the development and exploitation of geothermal energy in developing countries, held in Iceland and Italy, assessed the opportunities, options and constraints underlying geothermal energy development in developing countries and facilitated the exchange of experiences between developing and industrialized countries.

B. Technical publications

92. Developing countries are keenly interested in research in support of technical co-operation. In the energy field, research focuses on leading-edge technologies, the development of analytical tools, and the improvement of project implementation. It explores new directions, new methods and novel applications, while at the same time examining past experiences for valuable lessons to be learned.

93. The results of the Department's research are disseminated in the form of technical publications. Several important research topics are identified and examined each year. One recently completed technical paper in the area of energy is Energy Issues and Options for Developing Countries (New York, Taylor and Francis, 1989). It contains four technical studies: "Enhanced oil recovery", which provides an overview of the various methods, describing state-of-the-art technologies and present economics, and listing organizations and institutions where opportunities for training and technology transfer are available; "Small-scale hydropower programmes", which discusses all aspects of small-scale hydropower planning, economics and financing, development, operation, management and training; "Small energy packages", which examines all existing and potential energy sources in the rural environment and their applications, including packages for electricity generation utilizing internal combustion engines, micro-hydropower, photovoltaics, wind and biomass; and "Application of microcomputer technology in energy planning", which is designed to serve as a guide to planners and analysts on the subject of microcomputer-based energy planning. It provides criteria for model

design and selection, critical reviews of available software, issues in hardware procurement, and case studies in developing countries.

94. Some other recent technical reports are:

(a) "National energy information systems" (TCD/DNRE/E.10). This paper reviews the information requirements for the energy decision-making process; including energy pricing, energy investment, energy research, development and demonstration, emergency planning, energy system management, long-term planning, development strategies, energy demand, energy resources and energy technologies;

(b) "Joint hydropower development" (TCD/DNRE/E.11). This study relates the achievements made in Latin America and the Caribbean concerning joint hydropower development. It covers the following main topics: legal aspects; institutional and organizational agreements; financial feasibility; economic feasibility, including tariffs and taxing options; environmental impact assessment; and contribution to social and economic development;

(c) "Horizontal drilling in hydrocarbon exploration" (TCD/NRED/E.12). Improvements in equipment and directional drilling technology in recent years have produced several systems that can improve the economics of most reservoirs. Horizontal wells can increase production potential by minimizing the near-wellbore pressure drawdown and so reduce water and/or gas coning; increasing reservoir exposure; increasing the probability of intersecting fracture systems; and improving the geometry for enhanced recovery;

(d) "Economic evaluation of hydrocarbon exploration, production and investment" (TCD/NRED/E.14). The task of upstream oil industry analysts and observers is to define projects as well as possible within the constraints of financial forecasting and geological interpretation. Major commercial oil companies now employ rigorous technical and economic evaluation of all stages of upstream project management. It is this advance in analysis quality and technique, the raising of "commercial awareness", that leaves many national oil companies and energy ministers looking for ways to develop or rebuild their upstream industry in a disadvantaged position;

(e) "Small-scale coal mining" (TCD/NRED/E.13). This paper argues the case for small-scale coal mining in developing countries. Small coal mines offer several advantages - namely, less capital exposure, shorter pre-production time, easier use of contractors, adaptability of processing, easier disposal or sale, manageable water and environmental concerns and, in many cases, less required infrastructure;

(f) "Energy conservation in the power sector" (TCD/NRED/E.15). This paper draws attention to the important role which energy efficiency measures can play in reducing the need for investment in new plants in the power sector. It appraises cost- and energy-saving measures achievable through such things as systems planning, demand-side management, pricing, interconnection of networks, proper operation and maintenance procedures, rehabilitation of existing plants, and improved transmission and distribution schemes.

C. Other publications

95. Natural Resources Forum is a quarterly United Nations publication which seeks to meet the need for an international, multidisciplinary journal focused on the development of the water, energy and mineral resources of developing countries. Energy Newsletter is an annual publication which disseminates information on the activities of the Energy Resources Branch of the Department of Technical Co-operation for Development.

D. Energy-planning microcomputer software

96. Developing countries realize that the power and low cost of microcomputers make them an extremely useful tool for all types of overall energy planning and subsectoral analysis. However, in some areas, software that addresses the specific requirements of developing countries has been lacking. In response to the need, the Department of Technical Co-operation for Development has developed a trio of software applications which are now being used by energy planners in developing countries. These are the recently developed information system for national energy planning (ENERBASE), the energy modelling tool (ENERPLAN), and a new package for the presentation of energy balances in terms of useful energy (ENERUTIL). These three applications are being used as training tools in training workshops organized by the Department for energy planners. To date, over 100 participants from Africa, Asia, Latin America and the Caribbean have been trained in the use of these applications at various regional workshops. Available in English and Spanish, the three software packages are now being translated into French.

WORK PROGRAMME OF THE DEPARTMENT OF TECHNICAL CO-OPERATION
FOR DEVELOPMENT IN ENERGY FOR 1990

Country/region	Activity	Budget
<u>I. Energy policy, planning and conservation</u>		
Bangladesh	Strengthening in Energy Modelling	110 000
Ethiopia	Training in Energy Management	146 000
Ghana	Energy Policy and Operational Management	360 000
India	Energy Conservation Audits	488 000
Peru	Assistance to Centre for Energy Conservation	188 000
Latin America	Assistance to OLADE	320 000
Vanuatu	Energy and Petroleum Management	106 000
Zambia	Energy Conservation and Management	<u>175 000</u>
	Subtotal	1 893 000
<u>II. Petroleum, natural gas and coal</u>		
Belize	Petroleum and Minerals Investment Promotion	137 000
Chad	Petroleum Contract Negotiations	260 000
China	Enhanced Oil Recovery	52 000
China	Software Development for Petroleum Exploration	85 000
China	Marine Engineering Geology Investigation	75 000
China	Well Completion Techniques	778 000
India	Lab Facilities for Advanced Coal Techniques	66 000
India	Control of Water Systems in Coal Mining	86 000
India	Petroleum Engineering and Production Practices	42 000

Country/region	Activity	Budget
Iran, Islamic Republic of	Enhanced Oil Recovery	247 000
Iran, Islamic Republic of	Strengthening of Petroleum Training Capability	172 000
Jordan	Petroleum Investment Promotion	42 000
Peru	Promotion of Investment in Gas Development	64 000
Thailand	Human Resource Development Information System	23 000
Yugoslavia	Experimental Coal Mine Dredging	<u>12 000</u>
	Subtotal	2 141 000

III. Electricity

Bangladesh	Power Loss Reduction	344 000
Bhutan	Facility for Equipment Repair & Maintenance	144 000
China	Modernization of Coal-Fired Generating Unit	1 041 000
Egypt	Electricity/Energy Data Bank	582 000
Guinea-Bissau	Power Plant Rehabilitation	40 000
India	Training with Power Plant Simulator	518 000
Iran, Islamic Republic of	Electrical Network Planning	329 000
Nepal	Training of Hydropower Engineers	471 000
Viet Nam	Power Plant Upgrading	2 160 000
Yemen	Power System Loss Reduction	<u>160 000</u>
	Subtotal	5 789 000

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Country/region	Activity	Budget
IV. <u>Geothermal</u>		
China	Development and Use of Geothermal Energy	2 988 000
Philippines	Management of Geothermal Reservoirs	119 000
Caribbean	Exploration for Geothermal Resources	<u>514 000</u>
	Subtotal	3 621 000
V. <u>Solar and wind</u>		
Afghanistan	Solar Energy Development	340 000
China	Experimental Centre for Solar Heating/Cooling	289 000
Cuba	Production of Polycrystalline Silicon	88 000
India	Solar Energy Centre	764 000
India	Wind Energy Centre	480 000
Mongolia	Rural Solar and Wind Applications	473 000
Romania	Manufacture of Solar Photovoltaics	97 000
Viet Nam	Renewable Energy for Rural Areas	<u>88 000</u>
	Subtotal	2 619 000
	Total	16 063 000
